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MEMORANDUM OF THE CHAIRMAN

To Members of the Senate Committee on Energy and Natural Resources:

The following report was prepared in response to my request by the Congressional Research Service. I believe that this report contributes important insights on factors affecting the future need for additional uranium enrichment capacity.

According to the Department of Energy, $1.5 billion has been spent to date on the construction of the Gas Centrifuge Enrichment Plant (GCEP) at Portsmouth, Ohio. A further $613 million is requested for FY 1983 for a total of $2.15 billion. An additional $8 billion (as spent dollars) will be needed to complete this project according to the current Department of Energy Operating Plan.

JAMES A. MCCLURE, *Chairman.*

LETTER OF TRANSMITTAL

CONGRESSIONAL RESEARCH SERVICE,
THE LIBRARY OF CONGRESS,
Washington, D.C., May 11, 1982.

Hon. JAMES A. MCCLURE,
Chairman, Committee on Energy and Natural Resources, U.S. Senate, Washington, D.C.

DEAR MR. CHAIRMAN: In response to your request, I am submitting two reports on the need to build new plants for the enrichment of uranium. The first report, prepared at your request this past March, analyzes the need for new enrichment capacity solely from the perspective of whether the capacity is needed to meet anticipated demand. The second report was prepared by the Congressional Research Service (CRS) in April 1981. It examines the enrichment cost projections contained in the Department of Energy's "Uranium Enrichment Strategy Study" under low nuclear growth (low demand) conditions. Since the April 1981 CRS Report was first issued, numerous nuclear plants have been canceled and projections of the number of plants have fallen into the Strategy Study's low range.

Both CRS reports were written by Robert L. Civiak, Analyst in Energy Technology, Science Policy Research Division. The more recent of the two contains an appendix on the effect of plutonium recycle on enrichment requirements that was prepared by Warren H. Donnelly, Senior Specialist.

We hope these reports will serve the needs of your committee.

Sincerely,

GILBERT GUDE, *Director.*

CONTENTS

PART I—THE NEED FOR ADDITIONAL URANIUM ENRICHMENT CAPACITY TO MEET DEMAND

	Page
Issue definition	1
Introduction	1
Worldwide enrichment supply and demand	5
Demand for enrichment from the United States	8
Enrichment demand based on DOE nuclear capacity estimates	9
Potential for meeting the OUEA SWU demand estimate by reproduction	9
OUEA nuclear capacity to SWU demand conversion	11
Examination of DOE nuclear capacity estimates	15
U.S. nuclear generating capacity in 1995	15
Foreign nuclear capacity to be supplied by the United States in 1995	20
Other considerations that might affect SWU demand	23
Increased tails assay	24
Use of recycled plutonium	26
Summary and analysis	26
Meeting demand through preproduction and stockpiling	27
DOE may have overestimated demand	27
Reducing demand through increased tails assay	28
Appendix 1—Explanation of separative work units (SWU's) and tails assay	31
Appendix 2—The effect of plutonium recycle upon enrichment requirements	34

PART II—NECESSITY FOR GCEP UNDER LOW NUCLEAR POWER GROWTH CONDITIONS

The uranium enrichment strategy study	43
Results of the uranium enrichment study	45
350 GWe demand base case	48
250 GWe demand base case	49
208 GWe demand sensitivity case	50
Replacing existing diffusion plants with centrifuge plants	51
Conclusions	53
Tables:	
Table V–3. Summary of base case results	46
Table V–5. Sensitivity case summary: Low SWU demand	47

THE NEED FOR ADDITIONAL URANIUM ENRICHMENT CAPACITY TO MEET DEMAND

ISSUE DEFINITION

The Administration has requested $613 million for the Department of Energy (DOE) for FY 1983 to continue construction of a gas centrifuge uranium enrichment plant near Portsmouth, Ohio. Through FY 1982, $1.54 billion of a total estimated cost of $6.95 billion had been appropriated for the plant, which is scheduled to begin partial operation in 1989. DOE maintains that the plant is needed to meet the projected demand for enriched uranium for domestic and foreign customers, and that it will also lower the cost of the enrichment process. However, these claims are subject to question. This report examines DOE's claim that increased enrichment capacity is needed to meet future user demand. The economic justification for building the centrifuge enrichment plant was last examined by the Congressional Research Service in April 1981. 1/

INTRODUCTION

Only seven-tenths of one percent of the uranium found in the earth is the isotope U-235. The concentration of U-235 must be increased to 2-3 percent

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1/ U.S. Library of Congress. Congressional Research Service. Necessity for GCEP Under Low Nuclear Growth Conditions. Typed report by Robert Civiak. Apr. 2, 1981. Washington, 1981, 12 p.

94-207 O - 82 - 2

for the uranium to be used in most nuclear reactors. The process of increasing the concentration of U-235 in a supply of uranium is called enrichment. 2/

Until 1979, the United States Government met virtually the entire world demand for enrichment services, outside the Soviet bloc, from plants that were originally built to meet U.S. defense needs. 3/ However, two European consortia now compete with the U.S. for enrichment sales, and additional foreign capacity is planned.

The existing U.S. plants use a gaseous diffusion process, which requires large amounts of electricity. In FY 1982, $800 million was appropriated for electric power charges in connection with gaseous diffusion. A new plant using a process based on gas centrifuges is currently under construction near Portsmouth, Ohio. The centrifuge technique is attractive because it requires only about five percent as much electricity to produce a given quantity of enriched uranium as the diffusion process. However, DOE estimates that the Gas Centrifuge Enrichment Plant (GCEP) will cost $6.9 billion to build, $1.54 billion of which has been appropriated through FY 1982. 4/

A third process, referred to as advanced isotope separation (AIS) is under development. There are currently three competing AIS processes, but selection of one process for further development is scheduled during FY 1982. AIS offers a process with a low capital investment requirement, low energy

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2/ Some basic concepts regarding enrichment are explained in Appendix 1.

3/ The plants are operated under contracts administered by the Department of Energy, which sells the enriched uranium produced under a mandate (P.L. 91-560) for "recovery of the Government's costs over a reasonable period of time."

4/ U.S. Department of Energy. Congressional Budget Request FY 1983. vol. 4, p. 211.

consumption, and low overall cost 5/. DOE believes that AIS technology could provide new enrichment capacity in the mid-to-late 1990's. 6/

The design of GCEP was initiated in FY 1976, and construction began in FY 1979. Since the project was initiated, increases in existing and planned enrichment capacity in the United States and abroad, together with a world-wide slowdown in nuclear power plant construction, have resulted in at least a short-term global oversupply of enrichment capacity. 7/ The plant was originally targeted for completion in 1986, but now only the first two of the full design of eight process buildings 8/ are scheduled for operation beginning in 1989, and Congress is considering further delay or possible cancellation of GCEP.

5/ Statement of Shelby T. Brewer, Assistant Secretary for Nuclear Energy, U.S. Department of Energy, before the Subcommittee on Energy and the Environment of the House Committee on Interior and Insular Affairs. Feb. 26, 1982.

6/ Ibid.

7/ U.S. Library of Congress. Congressional Research Service. Uranium Enrichment Services: Supply and Demand. Typed Report, by Robert L. Civiak, Mar. 4, 1981. Washington, 1981. 14 p.

Bauder, P., et. al. Competing for the non-USA Enrichment Markets. Nuclear Engineering International, Oct. 1980. p. 37-48.

MacLachlan, Ann. Uranium Enrichment: Goodbye to the Gung-ho Days of the 1970s. Energy Daily, Apr. 23, 1980. p. 4.

8/ The original plant design calls for 8 process buildings of 1.1 million SWU/year capacity each. (The unit for measuring enrichment, the SWU, is explained in Appendix 1.) DOE plans to complete the first two process buildings for operation with a capacity of 2.2 million SWU in 1989, and to complete the other buildings as demand warrents. Advanced centrifuges (set IV centrifuges), with a higher capacity than those planned for the first two buildings, are under development. DOE projects that set IV centrifuges will be available for buildings 3-8 and can be retrofitted to buildings 1 and 2. With set IV centrifuges in all 8 buildings, the plant capacity is projected to be 13.2 million SWU/year.

The Department of Energy maintains that GCEP is needed to meet future demand for enriched uranium. According to DOE Assistant Secretary for Nuclear Energy, Shelby Brewer, "Our projections indicate that capacity beyond what is currently available in the gaseous diffusion complex will be required in the 1990's." 9/ This report examines that conclusion. It first assesses the worldwide enrichment supply and demand situation in the near term and then takes a closer look at projections of the demand for U.S. supplied enrichment services in 1995. Projections beyond 1995 have a greater uncertainty, because potential demand arising from nuclear power plants that are not yet operating, under construction, or planned play an increasing role in longer term forecasts.

In addition to foreseeing a need for GCEP to meet demand, DOE projects that production from the centrifuge plant will be able to displace diffusion capacity and reduce the total cost of supplying enrichment services. Estimates of the cost of enrichment services depend heavily upon assumptions about the demand for enrichment and the availability of new technologies (set IV centrifuges and AIS technology) as well as a host of economic assumptions. DOE's assumptions and calculations which form the basis for its projection that completion of GCEP will lower enrichment costs are detailed in a 1980 report titled the Uranium Enrichment Strategy Study. 10/ The Congressional Research Service examined that study in April 1981, 11/ and found that

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9/ Statement of Shelby T. Brewer. op. cit.

10/ U.S. Department of Energy. Office of Uranium Resources and Enrichment. Uranium Enrichment Strategy Study. Washington, Oct. 1980. 269 p. Some of the calculations contained in the Strategy Study were updated in the "Uranium Enrichment Operating Plan" released by DOE in March 1982, but the findings were generally unchanged.

11/ U.S. Library of Congress. Congressional Research Service. Necessity for GCEP Under Low Nuclear Power Growth Conditions. Memorandum by Robert Civiak. Apr. 2, 1981. 10 p.

under conditions of low enrichment demand the projections of the Enrichment Strategy Study indicate that total enrichment enterprise costs may be higher if GCEP is built than if it is not built.

WORLDWIDE ENRICHMENT SUPPLY AND DEMAND

There is currently a worldwide excess of uranium enrichment capacity that has led producers to operate enrichment plants below their full capability. The maximum capacity of the U.S. Department of Energy's diffusion plants is 27.3 million SWU, but DOE produced only 9.6 million SWU in FY 1981, is scheduled to produce 9.8 million SWU in FY 1982, and plans to produce 9.8 million SWU in FY 1983. 12/ The exact production by foreign suppliers is not known, but during 1982, Eurodif, the largest foreign supplier, is expected to operate its plant at reduced pressure, which lowers the maximum possible production from 10.8 million SWU/yr to 8.5-9 million SWU/year. 13/ Eurodif is also reportedly planning reduced power operation. 14/

Table 1 is a summary of DOE estimates of foreign enrichment capacity. 15/ If the Soviet Union continues to export 3 million SWU/year and the other suppliers complete the capacity projected in table 1, then foreign enrichment

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12/ U.S. Department of Energy. Congressional Budget Request FY 1983. vol. 4, p. 112.

13/ Wolf, Walt. H. SWU Demand - Too Much and Too Little. Atomic Industrial Forum Fuels Conference. Mar. 16-18, 1981.

14/ Ibid.

15/ Statement of Shelby T. Brewer, op. cit.

capacity could be 19.0 million SWU/yr in 1990. If the 27.3 million SWU/yr capacity of the United States' diffusion plants is added to that, the total is 46.3 million SWU/yr. That amount of enrichment is sufficient to support about 386 gigawatts (Gw) of nuclear generated electricity. 16/

TABLE 1 -- Foreign Suppliers of Uranium Enrichment Services and Their Enrichment Capacity

Supplier	Capacity (millions of SWU/year)
USSR	3 to 4 available for export now.
URENCO 17/	0.6 operating; 2.0 committed; 3.0 possible by 1990.
EURODIF 18/	10.8 capacity, production will be at a lower level.
JAPAN	2.0 possible by 1990.
BRAZIL	0.2 possible by 1985.
AUSTRALIA	1.0 possible by 1995.

According to the most recent Nuclear News Survey 19/ there is 204 Gw of nuclear generating capacity operable, under construction or on order in the world outside the Soviet Union, Canada, and the United States. 20/

16/ The conversion factor used here is 0.12 SWU/Gw. The conversion between electrical capacity and SWUs is discussed beginning on page 11.

17/ Urenco is owned by a consortium of British, West German, and Dutch interests.

18/ Eurodif is owned by a consortium of French, Italian, Spanish, and Belgian interests.

19/ World List of Nuclear Power Plants. Nuclear News, Feb. 1982. p. 83.

20/ The Soviet Union is excluded from the calculation because they supply their own enrichment; Canada is excluded because Canadian reactors do not require enrichment; and the United States' capacity is added in later.

If 1) all that capacity is in operation in 1990; 2) no plants not yet ordered operate by 1990; and 3) DOE's estimate of the maximum U.S. nuclear capacity in 1990 (126 Gw) is added, then the total projected generating capacity to be supported by enrichment outside the Soviet Union in 1990 is 330 Gw, or about 85 percent of what could be served by DOE's projection of the free world's enrichment capacity. Because of construction delays, cancellations and other factors, it is unlikely that even as much as 330 GW of capacity will have to be served by enrichment plants outside the Soviet Union. Therefore, the world oversupply of enrichment capacity is very likely to last at least until 1990.

It is more difficult to forecast either the supply or demand for enrichment on a worldwide basis beyond 1990. However, the oversupply situation may continue for the following reasons.

— Nearly every country in the world with a nuclear power program has experienced a slowdown in nuclear reactor construction and a downward revision of its nuclear growth forecasts. 21/

— The continuing oversupply of enrichment capacity through the 1980's may be used to build up private and national inventories of enriched uranium that might be used in the 1990's to meet rising demand.

In addition, new enrichment capacity can be built more rapidly than nuclear power plants. Thus, if power plant orders increase, enrichment suppliers, including the United States, can build additional capacity to match the projected demand.

21/ Interdevelopment Inc. World Nuclear Power and its Fuel Cycle after Three Mile Island: A Guide for Marketing and Strategic Planning. 1981.

The international market for uranium enrichment is highly competitive. The United States has gone from a 100 percent share of the non-United States enrichment market in 1974 to about a 35 percent share today. 22/ In view of the oversupply of enrichment capacity through the end of the 1980's and the possibility that the oversupply will continue into the 1990's, it is prudent to examine projections of demand for enrichment from the United States carefully before building additional enrichment capacity.

DEMAND FOR ENRICHMENT FROM THE UNITED STATES

This section examines estimates of the demand for uranium enrichment services from the United States to the year 1995 and how the estimated demand might be met. The year 1995 is chosen because that is the latest year for which it can be safely assumed that few, if any, nuclear plants will operate that are not already in operation, under construction, or on order in the United States.

The Department of Energy's estimates of nuclear generating capacity to 1995, are first examined to determine whether the enrichment needed to meet that capacity could be met by production from the existing enrichment plants. DOE's nuclear capacity estimates are then examined to determine if they might be higher than can reasonably be expected. Finally, other factors that might reduce enrichment requirements are explored.

22/ Statement of Shelby T. Brewer. op. cit.

Enrichment Demand Based on DOE Nuclear Capacity Estimates

Table 2 gives the most recent (August 1981) mid-range estimate of the nuclear generating capacity that may seek enrichment services from the United States through 1995, and the separative work demand associated with that capacity, made by the Office of Uranium Enrichment and Assessment (OUEA) of DOE. As can be seen, the OUEA commercial SWU demand estimate does not exceed the 27.3 million SWU/yr capacity of the U.S. diffusion plants until 1994.

TABLE 2 -- OUEA Estimate of Nuclear Power Capacity and Separative Work (SWU) Requirements to be Met by U.S. Enrichment Production

Year	Nuclear Capacity (Gigawatts Electrical)			Separative Work (Millions of SWU)
	U.S.	Non-U.S.	Total	
1983	71.1	42.7	113.8	13.9
1984	80.2	43.8	124.0	18.8
1985	89.6	47.2	136.8	19.6
1986	99.9	50.8	150.7	18.7
1987	108.5	55.1	163.6	18.4
1988	115.6	56.5	172.1	21.2
1989	118.0	59.3	177.3	21.5
1990	122.0	59.7	181.7	23.2
1991	126.9	62.8	189.7	23.2
1992	129.2	65.8	195.0	24.5
1993	133.7	72.4	206.1	27.3
1994	134.8	81.1	215.9	27.4
1995	139.6	85.9	225.5	29.2

Potential for Meeting the OUEA SWU Demand Estimate by Preproduction

According to OUEA's projections, the commercial demand for enrichment will be greater than the 27.3 million SWU/yr capacity of the diffusion plants beginning in 1994. If U.S. defense needs for enriched uranium are added to the demand it may exceed production capacity before 1994. However, prior

to 1990, commercial demand is well below the full capacity of the enrichment plants, and a stockpile of enriched uranium could be built by overproducing in earlier years for use in the 1990's.

The DOE mid-range estimate of total commercial SWU demand between 1983 and 1995 (from table 2) is 300.8 million SWU. The total production capability of the diffusion plants over that 13 year period is 340.7 million SWU, assuming that the plants produce at 96 percent of their maximum capacity. 23/ That represents an excess production capacity above projected commercial requirements of about 40 million SWU. In addition, at the beginning of FY83 DOE will have a stockpile of enriched uranium containing about 27 million SWU, which it plans eventually to draw down to 8 million SWU. 24/ The excess production capacity plus the planned stockpile drawdown represent a total of 59 million SWU above commercial demand. However, some of this will be needed to meet United States defense needs to 1995.

The U.S. Department of Defense requires enriched uranium for fuel for nuclear powered vessels and for weapons programs. DOE has projected that the enrichment needs of the Naval Reactors program will be less than 18 million SWU between 1983 and 1995. 25/ Estimates of the uranium enrichment requirements of the U.S. weapons program are classified, however, the U.S. weapons arsenal relies predominantly upon plutonium from dedicated production reactors for

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23/ Uranium Enrichment Strategy Study. op. cit. p. 35

24/ U.S. Department of Energy. Uranium Enrichment Operating Plan. March 1982.

25/ Uranium Enrichment Strategy Study. op. cit. p. 33.

its fissile needs and there is a supply of enriched uranium from obsolete weapons. There have not been any withdrawals from the enrichment plants for weapons purposes since 1964. 26/ Unless U.S. weapons programs require more than 41 million SWU by 1995, the diffusion plants could be able to satisfy both defense and commercial enrichment requirements based on OUEA's mid-range estimate of commercial enrichment demand to 1995.

The cumulative commercial SWU demand from 1983 to 1995 associated with OUEA's "high" nuclear capacity growth estimate is 328.7 million SWU. 27/ If the same figures as above are used for the maximum production of the diffusion plants, the stockpile drawdown, and naval reactor requirements, then even with OUEA's high commercial demand estimate, 13 million SWU could be available for weapons programs between 1983 and 1995. Thus, it appears that production from the diffusion plants combined with the existing SWU stockpile could be sufficient to meet the largest commercial enrichment demand anticipated by DOE to at least 1995, unless a substantial amount of enrichment is required for weapons programs.

OUEA Nuclear Capacity to SWU Demand Conversion

Complex reactor models are used to determine the enriched uranium requirement per gigawatt of generating capacity. The model that OUEA uses takes into

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26/ Ibid.

27/ U.S. Department of Energy. Office of Uranium Enrichment and Assessment. OUEA August 1981 Civilian Annual Separative Work Demand Projections. 1981.

account the differing SWU requirements of different reactor types and the differences between initial fuel loadings and subsequent loadings. Hence, the conversion factor between OUEA's estimate of the nuclear generating capacity to be served in a given year and the SWU demand for that year varies. However, the average conversion factor from electrical gigawatts of nuclear capacity to millions of SWU, for the period 1983-1995, from table 2 is 0.1274.

This study has examined some of the assumptions of the model used to determine that conversion factor, and has identified two assumptions that may cause OUEA to overestimate the SWU demand associated with their nuclear capacity estimate.

The first questionable assumption is a change that DOE recently made in their model that resulted in about a 13 percent increase in the calculated value of the number of SWUs required per gigawatt for some reactors. 28/ Their justification for the change was that some customers had indicated plans to operate their reactors using longer refueling cycles, which require the added number of SWUs. 29/ DOE applied the 13 percent increased conversion factor to about 1/3 of all reactors, 30/ which increased the overall projected SWU requirement by about four percent.

Many utilities are examining the option of 18 month refueling cycles in place of the widely used 12 month cycle. However, other changes in nuclear

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28/ Uranium Enrichment Strategy Study, op. cit., p. 31.

29/ Ibid. p. 31

30/ Roger Gagne. DOE. Office of Uranium Enrichment and Assessment.

fuels are concurrently being considered which could reduce enrichment requirements. New boiling water reactor (BWR) fuels are being sold which reduce enrichment requirements by ten percent. 31/ New reactor fuels, called extended burnup fuels, are currently being developed that might reduce the enrichment consumption of all light water reactors. These fuels might make 18 month refueling cycles more attractive to utilities. However, with extended burnup fuel, enrichment requirements may be 0.3 percent to nine percent less than current enrichment requirements. 32/ Hence, DOE's assumption that 1/3 of reactor operators will shift to 18 month refueling cycles without considering the potential affect of extended burnup and other fuel improvements may not be justified. Thus, actual enrichment requirements may be up to four percent lower than that calculated by DOE.

That nuclear plants will operate with a 75 percent capacity factor is another arguable assumption that DOE uses in its calculation of the amount of uranium enrichment required per gigawatt of nuclear generating capacity. The capacity factor is the ratio of the actual electrical energy generated over a period of time to the maximum amount that could have been generated if the plant operated continuously. The higher a plant's capacity factor the more electricity it generates and the more fuel and enrichment it uses. Historically the average capacity factor for all light water reactors that

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31/ General Electric. Nuclear Energy Division. BWR Uranium Utilization Improvement Potential. 1 vol. in various pagings. June 1980. "GEAP-24965".

32/ Statement of N.L. Shapiro at Joint hearings before the House Committee on Energy and Commerce, Subcommittee on Energy Conversion and Power and the House Committee on Foreign Affairs, Subcommittee on International Economic Policy and Trade. Oct. 6, 1981.

have operated is below 60 percent. 33/ For a time, capacity factors increased as nuclear technology matured. In the United States during 1977 and 1978 capacity factors averaged 67 percent. 34/ However, since the accident at Three Mile Island in March 1979, the average capacity factor of U.S. reactors has been below 60 percent. 35/ Since the highest annual average nuclear plant capacity factor achieved in the U.S. has been 68 percent, DOE's use of a 75 percent capacity factor in its projections of the demand for enrichment may overestimate the actual amount of enrichment that will be required. The use of a 70 percent capacity factor instead of 75 percent would reduce the projected demand for enrichment by 6.7 percent.

If the impacts of assuming that nuclear plants move to 18 month refueling cycles, without extended burnup and other fuel improvements, and that they achieve 75 percent capacity factors are combined, then DOE may have overestimated the gigawatt to SWU conversion factor by ten percent or more. A ten percent reduction in the conversion factor for the number of SWUs required per gigawatt of generating capacity would reduce it from 0.0127 to 0.0114. A ten percent reduction in DOE's projected SWU demand for 1995 would reduce it from 29.2 million SWU to 26.3 million SWU. That level would require little, if any, preproduction of enriched uranium to meet civilian and defense demand for enrichment through 1995.

33/ Nuclear Station Achievement 1980. Nuclear Engineering International. Mar. 1981. p. 43.

34/ Atomic Industrial Forum. Public Affairs and Information Program. Nuclear Power Facts and Figures. Sept. 1980.

35/ U.S. Nuclear Regulatory Commission. Licensed Operating Reactors Status Summary Report (Gray Book). Vol. 5, no. 11, November 1981. NUREG-0020.

Examination of DOE Nuclear Capacity Estimates

The most recent (August 1981) projections of DOE's Office of Uranium Enrichment and Assessment (OUEA) were examined for the domestic and foreign nuclear generating capacity that might require enrichment services from the United States in 1995. In both cases the OUEA estimate may be higher than is justified.

U.S. Nuclear Generating Capacity in 1995

The OUEA August 1981 projection of the nuclear generating capacity in the United States in 1995 is 139.6 gigawatts. Since August 1981, 13 nuclear plants have been cancelled in the United States and 3 plants have been indefinitively delayed. 36/ Seven of those cancelled plants, with a capacity of 7.9 Gw, and the three indefinitely delayed plants, with a planned 3.7 Gw capacity, were included in the OUEA August 1981 projection of U.S. plants requiring enrichment in 1995. 37/ If the capacity of the cancelled plants is subtracted from OUEA's August projection, it is reduced to 131.7 Gw.

As of March 12, 1982 there were 157 plants with a total capacity of 149.31 Gw in the United States that had either received an operating license or a construction permit or were on order. This included 77 units with a

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36/ The cancelled plants are Black Fox units 1 and 2, Harris units 3 and 4, Callaway unit 2, Pilgram unit 2, Bailly, WPPSS Project units 4 and 5, Hope Creek unit 2 and Perkins units 1, 2 and 3. The indefinitely delayed plants are Hartsville units A1 and A2 and Yellow Creek unit 2. (Source: Various reports in Nucleonics Week.)

37/ The seven plants are Black Fox 1, Harris 4, Callaway 2, Pilgram 2, WPPSS 4 and 5, and Hope Creek 2.--Source: Luther Atkins. U.S. General Accounting Office from information supplied to GAO by DOE.

total capacity of 60.16 Gw that had been licensed or authorized to operate; 38/ 57 units with a total capacity of 62.26 Gw that had construction permits and for which construction was progressing; 39/ 14 units with a total capacity of 16.81 Gw that had construction permits, but for which construction had been indefinitely deferred; 40/ six plants with a capacity of 6.57 Gw that have pending construction permit applications; 41/ and three plants with a capacity of 3.51 Gw that have been ordered, but have not yet applied for construction permits. 42/

The 149 Gw capacity of these plants may be considered as an absolute upper limit on the nuclear capacity that could be in operation in the United States in 1995. That is because it currently takes 10-12 years to construct a nuclear power plant and the total lead time including planning, siting and

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38/ Includes the 71 plants listed in the November 1981 NRC "Gray Book" as licensed operating reactors plus Sequoyah unit 2, San Onofre unit 2, Diablo Canyon unit 1, Three Mile Island unit 2, Shippingport, and the Hanford N reactor. Does not include Dresden 1 and Humboldt which are shut down indefinitely and may not operate again.

39/ Includes the 78 plants listed in the December 1981 NRC "Yellow Book" with the exception of Hope Creek 2, Harris 3 and 4, and WPPSS 4 and 5, which have been subsequently cancelled; Diablo Canyon 1 and San Onofre 2, which have subsequently received low power operating licenses and are included with the operating reactors; and the 14 indefinitely delayed plants listed in the following footnote.

40/ The indefinitely deferred plants are Cherokee 1, 2 and 3, Clinton 2, Grand Gulf 2, Hartsville A1, A2, B1, and B2, Phipps Bend 1 and 2, River Bend 2, and Yellow Creek 1 and 2.

41/ Allens Creek 1, Skagit 1 and 2, Pebble Springs 1 and 2, and Clinch River.

42/ Vandalia and Carroll County 1 and 2.

licensing is about 14 years. 43/ In addition, no nuclear plants have been ordered in the United States since 1978 and most analysts do not expect any new orders for some years.

It is very unlikely that all 149 Gw will operate. In addition to the 13 plants cancelled since August 1981, 28 other previously ordered plants have been cancelled since January 1979 and 19 plants, for a total of 60, have been cancelled since January 1976. Despite support for nuclear power from the Reagan Administration, there are still formidable financial and regulatory problems facing nuclear power, which are likely to lead to additional plant cancellations. 44/ The staff of the Nuclear Regulatory Commission, estimates that 19 additional plants currently holding construction permits, and all the plants with pending construction permit applications except Clinch River, will be cancelled or indefinitely deferred. 45/

A detailed plant by plant analysis to attempt to determine which plants may be in operation by 1995 was not performed in this study. However, table 3 summarizes what might be considered conservative assumptions, for the purpose of planning enrichment demand of the nuclear generating capacity that may be in operation in 1995. The 126.3 Gw capacity from table 3 may be compared

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43/ U.S. Department of Energy. Office of Policy, Planning, and Analysis. Energy Projections to the Year 2000: A Supplement to the National Energy Policy Plan Required by Title VIII of the U.S. Department of Energy Organization Act (Public Law 95-91). Washington, D.C. July 1981. p. 10.1.3.

44/ Parisi, Anthony J. Hard Times for Nuclear Power. New York Times Magazine. April 12, 1981. p. 36.

45/ Memorandum from William J. Dircks, Executive Director for Operations, U.S. Nuclear Regulatory Commission to Commissioner John F. Ahearne. Subject: February 19, 1982 Request for Data. Mar. 8, 1982.

94-207 O - 82 - 4

with the recent NRC staff estimate that 114 Gw of nuclear capacity will be in operation in the United States in 1990 and that only one additional Gw will be added between 1990 and 2000. 46/

46/ Ibid.

TABLE 3 -- Effect of Various Assumptions on Nuclear Generating Capacity in the United States in 1995

Assumption	Plants	Capacity (Gigawatts)
Plants currently in the pipeline.	157	149.3
The plants that have not yet applied for construction permits do not operate by 1995.	-3	-3.6
3 of the 6 plants with pending construction permit applications operate by 1995.	-3	-3.3
3 of the 8 indefinately deferred plants owned by the Tennessee Valley Authority (TVA) operate by 1995. 47/	-5	-6.1
The non-TVA, indefinitely deferred plants less than 2% complete do not operate by 1995. 48/	-4	-4.4
5 additional plants under construction are cancelled or deferred beyond 1995.	-5	-5.5
All licensed plants continue to operate except Shippingport, which is closed down in 1983 as scheduled.	-1	-0.1
TOTAL	136	126.3

The 13.3 Gw difference between OUEA's projection of 139.6 Gw and an estimate of 126.3 Gw for nuclear capacity in the United States in 1995 represents a potentially reduced enrichment demand of about 1.5-1.6 million SWU for that year.

47/ Branscome, James. TVA's Nuclear Program Likely to be Halved by Years End. Nucleonics Week. Vol. 23, no. 10, Mar. 11, 1982. p. 1.

48/ Cherokee 2 and 3, Clinton 2, and River Bend 2.

Foreign Nuclear Capacity to be Supplied Enrichment by the U.S. in 1995

It is more difficult to estimate foreign demand for U.S. enrichment than domestic demand, because less information is available concerning foreign reactors under construction. In addition, in some countries nuclear plants can be licensed and built in under ten years so that plants for which construction has not yet begun may require enrichment by 1995. The situation is further complicated because there are several suppliers, besides the U.S., from which foreign customers may purchase enrichment.

The Office of Uranium Enrichment and Assessment bases its mid-range estimate of 85.9 Gw of non-U.S. capacity to be served by U.S. enrichment in 1995 mostly upon contracts it already holds for the sale of enriched uranium, although a small number of anticipated new contracts are included in the estimate. However, almost every country with a nuclear power program has experienced slowdowns in ther program 49/ and many of DOE's contracts may be for plants that will not operate by 1995 if they are built at all. In addition, foreign enrichment customers might switch from DOE to alternate enrichment suppliers, if they have an opportunity to do so, because they have their own domestic sources, for economic reasons, or to improve their assurance of supply. OUEA claims to takes these possibilities into account in its projections, but it is difficult to verify how accurate their projections are.

49/ Interdevelopment Inc. World Nuclear Power. op. cit.

The nuclear programs in all countries with contracts with DOE were not examined. However, 42.5 Gw of the total 85.9 Gw of foreign capacity that OUEA projects will be supplied by DOE in 1995 is in Japan. Hence, the nuclear power program in that country merits close attention.

Since 1979, the official Japanese goal for nuclear generating capacity has been 51 Gw in 1990 and 74-78 Gw in 1995. 50/ However, chiefly due to siting problems, and slow electricity demand growth the Japanese nuclear program has not maintained the growth anticipated and the official estimates are expected to soon be revised downward. 51/ The new target for 1990 is expected to be in the area of 40-45 Gw. 52/ However, even this reduced figure is a goal rather than a projection of what capacity may actually be in operation. As of November 1981 in Japan, 22 reactors with a capacity of 15.5 Gw were in operation, 11 reactors with a capacity of 10.1 Gw were under construction and five reactors with a 5.3 Gw capacity were planned, but had not yet received construction permits. 53/ The total planned capacity of these plants is 30.9 Gw.

50/ Ushio, Shota. Official Estimate Slashed for Japan's 1990s Nuclear Capacity. Nucleonics Week, Oct. 29, 1981. p. 2.

51/ Ibid.

52/ T. Tanabe. Director, Nuclear Energy Industry Division, Japanese Ministry of International Trade and Industry. (From notes and materials supplied by Elliot Chakoff of the Senate Energy and Natural Resources Committee. Jan. 1982.)

53/ Ibid.

While the construction time for nuclear power plants in Japan is only about six years, the time from initial site discussions to completion of a plant may be as long as 15 years. 54/ The last two of the planned plants included above are scheduled for completion in 1989. If all the plants included above and an additional 3 plants are completed by 1990, the total Japanese nuclear generating capacity would be about 34 Gw instead of the official goal of 40-45 Gw. If an additional 13 Gw are added by 1995, the capacity in that year would be 47 Gw. That would require a maintainance of the same rate of nuclear growth as projected for the 1980's, which in view of the continued worldwide slowdown in nuclear growth may be a somewhat high estimate, but nevertheless is well below the old projection of 74-78 Gw.

In view of the possibility of this considerable slowdown of the Japanese program it is questionable whether they will actually purchase enrichment to support 42.5 Gw from DOE in 1995 as projected by OUEA in its mid-range projection. The estimated 42.5 Gw capacity might be about 90% of the total Japanese nuclear capacity in 1995. The Japanese may seek to diversify their sources of enrichment rather than rely upon the United States for such a large share of their needs. In that case, the OUEA "low" projection for Japan of 31.1 Gw may be more realistic than their mid-range projection for 1995.

In addition to the good possibility of a lower nuclear capacity in Japan in 1995 than has been the official goal, there is a possibility

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54/ Interdevelopment Inc. World Nuclear Power. op. cit.

that there will be a new commercial enrichment plant in operation in Japan by 1995. According to T. Tanabe of the Japanese Ministry of International Trade and Industry (MITI), 55/ construction on an enrichment plant will start in 1986, and production of three million SWU/yr is scheduled for the early 1990's. The U.S. DOE projects that Japanese enrichment capacity may reach two million SWU/yr by 1990 (see table 1). A two million SWU/yr plant could supply the enrichment needs of 16-18 Gw of nuclear capacity, and may greatly reduce the amount of enrichment that Japanese reactor operators purchase from the United States.

In summary, Japanese nuclear development has been slower than official goals and there is a good probability that an enrichment plant will be in operation in Japan by 1995. Hence, the OUEA estimate for enrichment demand from Japan may be too high by as much as 10-20 Gw. That capacity is equivalent to about 1.2-2.4 million SWU/yr in enrichment.

Other Considerations That Might Affect SWU Demand

In addition to the factors previously discussed, there are other considerations that might reduce the demand for SWUs from that projected by OUEA. These include 1. the option of operating the diffusion plants with greater than a 0.20 percent tails assay and 2. the possibility that reprocessing of spent fuel and the use of plutonium in light water reactors will further reduce the demand for enriched uranium.

55/ T. Tanabe. op. cit.

Increased Tails Assay

Increasing the tails assay 56/ at the enrichment plants is an action that DOE could take to reduce the amount of SWUs it must produce to satisfy demand. As explained in Appendix 1, there is a tradeoff possible between the amount of separative work (number of SWUs) required and the amount of natural (unenriched) uranium consumed to produce a quantity of uranium enriched to a given percentage. By increasing the operating tails assay from its current value of 0.20 percent to 0.30 percent, about 21 percent fewer SWUs would have to be produced to satisfy the same demand for enriched uranium. 57/ However, about 20 percent more uranium feed would be required. DOE last operated the enrichment plants with a tails assay of 0.30 percent from 1971 to 1976. 58/

Since uranium resources are somewhat limited, there may be reason to conserve it in the long term. However, at the current time because of the slow rate of growth of nuclear power, demand for uranium is falling. Uranium prices are the lowest they have been since 1976, and DOE estimates that the amount of uranium mined in the United States will be cut back from 21,850 tons of U308 in 1980 to 15,500 tons in 1982. 59/ Employment in the uranium industry has fallen from 22,000 people in 1979 to 15,000 people at the end

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56/ The meaning of tails assay is explained in Appendix 1.

57/ See Table 4 in Appendix 1.

58/ Ahmed, S. Basheer. Nuclear Fuel and Energy Policy. Lexington, Mass., D.C. Heath. 1979. p. 116.

59/ Statement of Shelby T. Brewer. Op. cit.

of 1981. 60/ In addition, DOE has built up a stockpile of about 90,000 tons (U3O8 equivalent) of unenriched uranium. 61/

Hence, if DOE increases the operating tails at its diffusion plants, the extra feed required could be made up from DOE's uranium stockpile or by increased domestic production. At a later date, if uranium prices rise or uranium production capacity is strained, the uranium remaining in the tails could be recovered by returning the tails to enrichment plants and then operating at a lower tails assay. In this sense, increasing the operating tails assay can be seen as a means of deferring the need for additional enrichment capacity. If reenrichment of the tails is deferred to the late 1990s or beyond 2000, enrichment plants using AIS techniques, with the possibility of greatly reduced costs, may be in operation.

The operating tails assay at the enrichment plants can be increased at any time. Hence, if construction of new enrichment capacity is deferred and the operating tails assay is kept at 0.20 percent, the 20 percent or more reduction in enrichment requirement that can be achieved by increasing the tails assay can be viewed as a margin of safety against possible unanticipated increases in enrichment demand.

60/ Ibid.

61/ U.S. Department of Energy. Uranium Enrichment 1980 Annual Report. 1981. p. 20.

Use of Recycled Plutonium

In theory, plutonium could be recovered from spent nuclear fuel by a chemical process called reprocessing. It could then be mixed with natural (unenriched) uranium to provide new fuel in place of currently used enriched uranium. The possibility that enrichment demand in the 1990s may be reduced by the use of recycled plutonium is analyzed in detail in Appendix 2. The finding of that analysis is that, while in theory extensive recycle of plutonium could reduce enrichment demand by 25 to 35 percent, the industrial facilities needed to recover the plutonium do not exist on the scale necessary. Furthermore, at the current time, plans for new reprocessing plants hold little promise that enough commercial plutonium will be produced to notably reduce the demand for enrichment for the next two decades.

SUMMARY AND ANALYSIS

This study has examined the Department of Energy's claim that new enrichment capacity is needed in the United States to meet the projected demand for enriched uranium for domestic and foreign customers. It is found that the Department of Energy's claim that additional enrichment capacity is needed to meet demand is questionable for three reasons:

1. The enrichment demand projected by DOE might be met, at least to 1995, by preproduction and stockpiling of enriched uranium;

2. DOE's estimate of the demand for enrichment through 1995 may be too high; and

3. DOE could reduce the need for enrichment capacity by increasing the operating tails assay at the diffusion plants.

Meeting Demand Through Preproduction and Stockpiling

According to DOE's mid-range projection, the demand for enrichment for domestic and foreign nuclear power plants exceeds the maximum production capacity of the diffusion plants in 1994. In DOE's high estimate, commercial demand exceeds the capacity of the diffusion plants in 1991. Additional enrichment is needed for defense purposes.

However, if the existing diffusion plants are operated at their maximum capacity beginning in 1983, and the excess enriched uranium stockpiled, the cumulative production of the plants could be about 13 million SWU above that needed to meet the maximum commercial enrichment demand projected by DOE through 1995 plus the projected requirements of the naval reactors program. The cumulative production from 1983 to 1995 could be about 41 million SWU above that needed should DOE's mid-range estimate of commercial demand hold true. Hence, unless a considerable amount of enrichment is needed for weapons programs, using DOE's own figures, production from existing enrichment plants could be sufficient to meet the total demand to at least 1995.

DOE May Have Overestimated Demand

Actual commercial demand might be considerably below DOE's mid-range projection. Since August 1981, when DOE made its demand estimate, seven domestic nuclear plants, with a capacity of 7.9 Gw, that were included in DOE's mid-range projection for 1995 have been cancelled. With additional cancellations likely, there is a good possibility that domestic nuclear capacity in 1995 will be no more than 126.3 Gw, which is 13.3 Gw below

the DOE August 1981 estimate. While foreign capacity requiring U.S. enrichment is more difficult to project, it appears that the DOE mid-range projection may overestimate demand in 1995 by 10-20 Gw from Japanese sources alone. If DOE's projected domestic nuclear capacity for 1995 is reduced by 13.3 Gw and its foreign capacity projection reduced by 10 Gw, then only 202.2 Gw instead of DOE's estimate of 225.5 Gw would have to be supplied with enrichment in 1995.

In addition, the model that DOE uses to calculate enrichment demand from its nuclear generating capacity projections may overestimate the number of SWUs needed by as much as ten percent. If a gigawatt to SWU conversion factor reduced by only five percent from DOE's value is applied to the above reduced nuclear capacity projection, then the projected demand for enrichment in 1995 would be 24.9 million SWU instead of the 29.2 million SWU projected by DOE. That demand is well below the 27.3 million SWU maximum yearly production capacity of the diffusion plants.

The possibility that reprocessing and the use of plutonium as a reactor fuel might further reduce demand for uranium enrichment was examined, but it was found that there is little promise that enough commercial plutonium will be produced to notably reduce the demand for enrichment for the next two decades.

Reducing Demand Through Increased Tails Assay

DOE has at its disposal the option of increasing the operating tails assay at the diffusion plants. An increase in the operating tails assay from 0.2 percent to 0.3 percent, which is what it was from 1971 to 1976, would reduce the amount of separative work (SWUs) that has to be produced to meet the

demand for enriched uranium by 20 percent. If the tails assay is increased, additional uranium feed would be required to supply the same amount of enriched uranium. However, if the tails assay is kept at 0.2 percent, the option of increasing the tails assay at a later date could be viewed as a margin of safety against possible unanticipated increases in enrichment demand.

It appears that annual commercial demand for enrichment may remain below the production capacity of the existing diffusion plants to at least 1995, without increasing the operating tails assay. If demand should exceed production capacity 62/ or if it is desired to meet demand beyond 1995 without building additional enrichment capacity, then the increased demand might be met by preproduction and stockpiling of enriched uranium or by increasing the operating tails assay of the enrichment plants. Hence, it could be possible to meet enrichment demand without building additional enrichment capacity in the United States until AIS technology is available in the mid-to-late 1990's.

However, it should be emphasized that this study has examined only the need for new enrichment capacity to meet demand. There may be other reasons for completing the gas centrifuge plant that is currently under construction. Centrifuge enrichment uses about one-twentieth the amount of energy consumed to produce the same amount of enrichment as diffusion, and the Department of Energy believes that completion and operation of the Portsmouth Gas Centrifuge Enrichment Plant (GCEP) will reduce the total cost of producing

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62/ For example if large amounts of enrichment is required for weapons programs.

enriched uranium. 63/ 64/ In addition, cancellation of GCEP may cause centrifuge manufacturers to close their plants, which could foreclose the option of using centrifuge technology for many years. While AIS technology appears promising, it is still unproven. Hence, it may be premature to foreclose the option of building a centrifuge enrichment plant.

63/ Statement of Shelby T. Brewer. op. cit.

64/ The Congressional Research Service examined DOE's economic assessment of completing GCEP in April 1981 and found that in low enrichment demand scenarios it is questionable whether completion of GCEP will reduce the total cost of producing enriched uranium. See Necessity for GCEP Under Low Nuclear Growth Conditions. Op. cit.

APPENDIX 1

EXPLANATION OF SEPARATIVE WORK UNITS (SWUs) AND TAILS ASSAY

The unit of measure of uranium enrichment services is the separative work unit (SWU), which reflects the effort required to separate the isotopes of uranium. In order to produce a quantity of uranium enriched in U-235 one must simultaneously produce uranium depleted in U-235. This "left over" uranium is called the tails and the percentage of U-235 in the tails is the tails assay. There is a tradeoff between the amount of separative work (number of SWUs) required and the amount of natural uranium consumed to produce a quantity of uranium enriched to a given percent. The tradeoff is determined by the amount of U-235 one chooses to leave unused, i.e. the tails assay. More natural uranium is required and fewer SWUs used if the tails assay is higher. Table 4 shows how the tails assay affects the tradeoff between the natural uranium consumed and the separative work required to produce one kilogram of three percent U-235 enriched uranium.

For example, to produce one kilogram of uranium enriched to three percent U-235 would require 5.5 kilograms of natural uranium and 4.3 SWU if the tails were left with 0.2 percent U-235.

TABLE 4 -- Tradeoff Between Uranium Feed and SWUs 65/

	Tails Assay (percent)		
	0.20	0.25	0.30
Uranium feed (kilograms)	5.5	6.0	6.6
Separative work (SWUs)	4.3	3.8	3.4

In practice the choice of tails assay is determined by factors including the price of uranium, the price of enrichment services and policy considerations regarding extending uranium supplies.

A distinction may be made between two types of tails assay. The operating tails assay refers to the actual concentration of U-235 left in the depleted uranium that leaves the enrichment plant. The transaction tails assay is determined by the agreement between the customer and the enrichment supplier, and may be different from the operating tails assay. The transaction tails assay is generally used to calculate the amount of unenriched uranium feed that the customer must provide. If enrichment sales are carried out with the transaction tails assay greater than the operating tails assay, more uranium will be supplied than is used, and the enrichment supplier will accumulate an excess of unenriched uranium. If the transaction tails assay is less than the operating tails assay, the enrichment supplier will have to

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65/ U.S. Congress. Senate. Committee on Energy and Natural Resources. Subcommittee on Energy, Research, and Development. Uranium Enrichment Policy. Hearing, 95th Cong., 2d Sess., Feb. 8, 1978. Washington, U.S. Govt. Print. Off., 1978. p. 25.

make up the difference between the uranium provided by the customer and the amount used. This provides a mechanism for managing the flow of materials required for enrichment services.

APPENDIX 2

THE EFFECT OF PLUTONIUM RECYCLE UPON ENRICHMENT REQUIREMENTS 66/

Ever since the early days of the Manhattan Project, many have been intrigued with the idea that uranium-238, which is useless as a nuclear fuel, can be transformed into a useful fuel, plutonium, by exposing it to neutrons in a reactor. In theory, this plutonium could be recovered from the exposed uranium (spent fuel) by a chemical process called reprocessing, and then could be mixed with normal uranium to provide a nuclear fuel, equivalent to slightly enriched uranium for use in light water reactors, or used in concentrated form in breeder reactors. Nuclear proponents expect recovered plutonium to be used in both ways, to supplement fuel supplies for conventional unclear power reactors, and as the primary fuel for breeders if and when they come into commercial use. To date, however, there has been no commercial reuse, or recycling, of plutonium back into conventional power reactors.

If and when plutonium recycle will ever become a commercial reality remains to be seen. Many uncertainties make it futile to attempt to definite forecast. These include questions about the economics of reprocessing and plutonium fuel fabrication, the effect of a "plutonium economy" upon risks of further spread of nuclear weapons and the ability to make them, and risks that a greater presence of plutonium in commerce would increase risks of its seizure and misuse by terrorists or other violent organizations. In addition, regulatory bodies of many countries would have to be convinced that commercial

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66/ Prepared by Warren H. Donnelly, Senior Specialist.

production and use of plutonium would not unacceptably increase risks of accidents and radioactive contamination from nuclear power plants.

However, with a few assumptions, it is possible to illustrate the kind of effect commercial plutonium recycle might have upon demand for enrichment. Common sense says that the more plutonium can be substituted for uranium-235, the less enriched uranium will be needed, with a corresponding reduction in demand for enrichment services. The greatest effect would come if plutonium could entirely replace enrichment uranium in nuclear fuel. However, this option does not rank high in current thinking. More likely is use of plutonium as a supplement. Typically, a conventional nuclear power plant of 1000 MW capacity, after it has started up, needs about 37 metric tons of low enriched uranium annually. 67/ This annual amount could be reduced to 24.6 metric tons by substitution of about 457 Kg of plutonium mixed with about 11.3 metric tons of normal uranium. This estimate includes also the saving from recovery and reuse of residual enriched uranium from the spent fuel. Estimates of how much enrichment would be saved vary with assumption. A Department of Energy report in 1978 said savings could range from 25 to 35 percent. 68/ More recently, in February 1980, a report of the International Nuclear Fuel Cycle Evaluation indicated a saving of 35 percent or more with light water reactors. 69/

67/ International Nuclear Fuel Cycle Evaluation. Reprocessing, plutonium handling, recycle. Report of Working Group 4. Vienna: International Atomic Energy Agency, 1980, p. 52.

68/ U.S. Dept. of Energy. Barnwell Nuclear Fuels Plant Applicability Study, v. II, Apr. 1978 (Report DOE/ET-0040/2), p. 5-6.

69/ INFCE Working Group 4, op. cit., p. 53.

Applying the postulated saving of 35 percent to the enrichment demand figures in table 2 produces the illustrative figures of table 5.

TABLE 5. Illustration of Maximum Potential Reduction in Separative Work (SWU) Requirements from Recycle of Plutonium as Nuclear Fuel

Year	Nuclear Capacity Total (Gigawatts Electrical)	Separative Work (Millions of SWU)	Reduced Separative Work @ 25% saving	@ 35% saving
1983	113.8	13.9	10.4	9.0
1984	124.0	18.8	14.1	12.2
1985	136.8	19.6	14.7	12.6
1986	150.7	18.7	14.1	12.1
1987	163.6	18.4	13.8	12.0
1988	172.1	21.2	15.8	13.8
1989	177.3	21.5	16.2	14.0
1990	181.7	23.2	17.3	15.1
1991	189.7	23.2	17.3	15.1
1992	195.0	24.5	18.3	15.9
1993	206.1	27.3	20.6	17.7
1994	215.9	27.4	20.6	17.7
1995	225.5	29.2	21.9	19.0

How much enrichment can be saved depends also upon how much plutonium is available. Drawing again on INFCE's report, table 6, shows the amounts of plutonium that would be needed annually to achieve these enrichment savings. Plutonium needs could range from 31-44 metric tons in 1983 to 65-91 in 1995, depending upon the assumption of 25 percent or 35 percent postulated savings.

The potential for plutonium recycle is affected by many factors, including the amount of plutonium in the spent fuel discharged from nuclear power plants and by the industrial capacity to recover that plutonium in reprocessing plants. Concerning the plutonium in spent fuel, depending upon assumptions, a 1000 MW nuclear power plant typically produces some 35.7 metric tons a year. Of this, somewhat more than one percent would be plutonium. The figure used by INFCE in its estimates is 480 Kg of plutonium per year for a 1000 MW power plant. 70/

Table 7 shows how much plutonium would be produced annually by the nuclear capacity estimated in table 2.

70/ Ibid., p. 52.

TABLE 6. Illustrative Amounts of Plutonium Needed to Achieve Savings of Table 5

Year	Savings @ 25% (Million SWU)	Pu Needed (metric tons)	Savings @ 35% (Million SWU)	Pu Needed (metric tons)
1983	3.5	31.5	4.9	44.0
1984	4.7	42.3	6.6	59.4
1985	4.9	44.0	7.0	63.0
1986	4.6	41.4	6.6	59.4
1987	4.6	41.4	6.4	57.5
1988	5.4	48.5	7.4	66.5
1989	5.3	47.6	7.5	67.4
1990	5.9	53.0	7.1	64.0
1991	5.9	53.0	7.1	64.0
1992	6.2	56.7	8.6	77.2
1993	6.9	62.0	9.6	86.1
1994	6.9	62.0	9.6	86.1
1995	7.3	65.0	10.2	91.6

Sample calculation for 1983

Plutonium needed = SWU x 9 metric tons plutonium/million SWU

= 3.5 x 9 metric tons

= 31.5 metric tons

TABLE 7. Illustration of Plutonium Production by Estimated Nuclear Power Capacity

Year	Total Nuclear Capacity (Gigawatts Electric)	Typical Yearly Plutonium Production (Metric Tons)
1983	113.8	54.5
1984	124.0	59.5
1985	136.8	65.4
1986	150.7	72.3
1987	163.6	78.5
1988	172.1	82.6
1989	177.3	85.1
1990	181.7	87.0
1991	189.7	91.0
1992	195.0	93.6
1993	206.1	98.9
1994	215.9	103.0
1995	225.9	108.0

Sample calculation for nuclear capacity 1983.

Amount of plutonium = Nuclear capacity x plutonium per year

= 113.8 GW x 0.48 metric tons/Gw — year = 54.5 metric tons

These illustrative figures suggest that while enough plutonium could be produced to supply recycle, most of the spent fuel generated would have to be reprocessed. However, the potential supply of separated plutonium is so much less than the amounts needed that unless reprocessing capacity is expanded dramatically, the suggested enrichment savings will remain hypothetical. Note too, these figures contain no allowance for plutonium needed to start up com-commercial fast breeders.

At present only one large reprocessing plant is in operation, that of France at Le Hague. It can currently process about 160 metric tons of spent fuel a year to separate about 1.1 metric tons of plutonium a year. The French expect to increase the capacity of Le Hague to 800 metric tons per year by 1992 which could provide about 5.6 metric tons a year. 71/

As for the British plant at Windscale, it is equipped only to reprocess fuel from British Magnox type reactors and cannot handle LWR spent fuel. Construction has yet to begin for an additional to handle the latter. The Japanese have a pilot plant in operation and there are signs that an industrial scale plant may be built. At best, however, this Japanese plant would not be operable until the late 1980s. The U.S. nuclear industry has a new but never used reprocessing plant at Barnwell, South Carolina, which was designed to reprocess 1500 metric tons a year which might produce about 20 metric tons of plutonium annually. Its future is the subject of controversy.

71/ Information from the Office of the Nuclear Attache, Embassy of France, Mar. 18, 1982.

Taken together, these illustrative figures indicate that while in theory commercial recycle of plutonium could reduce the demand for DOE enrichment for domestic and foreign nuclear power, the industrial facilities needed to recover this plutonium do not exist on the scale necessary. At the moment, plans for new reprocessing plants here or abroad hold little promise that enough commercial plutonium could be produced to notably reduce the demand for enrichment for the next two decades.

NECESSITY FOR GCEP UNDER LOW NUCLEAR POWER GROWTH CONDITIONS

The domestic and international situation regarding the supply and demand of uranium enrichment services has been reviewed previously by the Congressional Research Service. 1/ That report noted that production from the gas centrifuge enrichment plant (GCEP), currently under construction near Portsmouth, Ohio, would not be needed to meet projected demand until some time after 1990, but that other considerations (primarily cost and energy savings) might justify the early completion of the plant. This report further examines the justification for early completion of GCEP under the assumption of low nuclear power growth.

This analysis is based heavily upon the Department of Energy's (DOE) recently completed Uranium Enrichment Strategy Study. 2/

The CRS report on enrichment supply and demand contains a discussion of the basic structure of the uranium enrichment enterprise, including definitions of terms such as "tails assay" and "separate work units" (SWUs), and that will not be repeated here.

THE URANIUM ENRICHMENT STRATEGY STUDY

The Uranium Enrichment Strategy Study (UESS) is intended to aid in making management decisions regarding the operations of the uranium enrichment enterprise.

1/ U.S. Library of Congress. Congressional Research Service. Uranium Enrichment Services: Supply and Demand. Typed report by Robert Civiak, Mar. 4, 1981. Washington, 1981. 14 p.

2/ U.S. Dept. of Energy. Office of Uranium Resources and Enrichment. Uranium Enrichment Strategy Study. Washington, Oct. 1980. 269 p.

Decisions to be made involve: the amount of power to use in the diffusion plants; the rate of introduction of new technologies, i.e., centrifuge and advanced isotope separation (AIS) technologies; the tails assays to use; and the maintenance of stockpiles of enriched and natural uranium.

The study uses a complex model which makes assumptions regarding the capital and operating costs of the various enrichment technologies, the demand for enrichment, the price of uranium, and assumptions about the economy. These assumptions are combined with various operating decisions, to predict the resultant total cost of enrichment over the 30 year period 1980-2010. In addition to total costs, the model projects the cost per SWU, the amount of uranium consumed, the levels of government uranium stockpiles, the power consumed, and the annual Government costs of enrichment for each of the next 30 years. All of these projections, as well as the risks involved in various management strategies, should be considered in deciding how to manage the uranium enrichment enterprise.

The UESS examines several different combinations of enrichment technologies under two different demand assumptions in its "base case." It then examines variations of the base case assumptions in a series of "sensitivity case studies." The two base case demand situations are for the U.S. to supply enriched uranium for 250 and 350 gigawatts-electrical (GWe) of domestic and foreign nuclear capacity in the year 2000. These demands compare with DOE's June 1980 mid-range prediction that 308 GWe will have to be supplied by U.S. enrichment plants in 2000. However, this projection assumes that utilities will order some new nuclear plants. No new nuclear plants have been ordered in the U.S. since 1978. If no nuclear plants are ordered in the future, demand for enrichment will be considerably lower than DOE's mid-range prediction. This possibility is examined in one of the sensitivity studies of the UESS, which assumes that most, but

not all of the nuclear plants currently under construction will be completed and that no new plants will be ordered. In that case, it is assumed that U.S. enrichment plants will supply a total of 208 Gwe of capacity beginning in 1993 and continue at that level through 2010.

RESULTS OF THE URANIUM ENRICHMENT STUDY

Tables V-3 and V-5 from the Uranium Enrichment Strategy Study are reproduced on the following pages. These tables summarize the base case and the low demand sensitivity case projections from the UESS. The first column in each of tables V-3 and V-5 lists various combinations of technologies that can be used to satisfy the demand for enrichment--GDP refers to the existing gaseous diffusion plants; GCEP (set III) refers to the Portsmouth GCEP with the set III centrifuges, which are currently available; GCEP (set IV) refers to the Portsmouth plant with set IV centrifuges, which are expected to be available in 1990 3/; GC refers to additional centrifuge plants with set III centrifuges; AGC refers to additional plants with set IV or more advanced centrifuges; and AIS ('90) and AIS ('95) refer to introduction to advanced isotope separation techniques in 1990 and 1995 respectively.

The second column of each table gives the 30-year total cost in 1980 dollars (discounted to the present at 10 percent per year) to produce enriched uranium. This cost includes the cost to DOE customers of supplying uranium feed, as well as DOE's costs (which must be recovered by enrichment sales) incurred in the

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3/ The set IV centrifuges are expected to have a capacity 50 percent greater than the set III centrifuges at the same cost to manufacture and operate. They are currently in the engineering development phase, but DOE believes that they could be ready for installation into the GCEP plant by 1990.

Table V-3

SUMMARY OF BASE CASE RESULTS

	Discounted Total Enterprise Cost ($ × 10^9)	Discounted Governmental Cost ($ × 10^9)	30-year Total GDP Energy Usage (GW-yr)	Peak Requirement for Feed from U.S. Mining Industry MTU/yr	Peak Requirement for Feed from U.S. Mining Industry Date	30-Year-Average Separative Work Cost ($/SWU)	Year Minimum Product Stockpile Reached	Highest Operating Tails Assay (%)
250-GW(e) Demand								
GDP + GCEP (Set III) + GC (Set III)	56.90	20.04	170	33,700	2009	75.13	1988	0.225
GDP + GCEP (Set IV) + AGC	54.72	18.37	138	23,400	2009	56.32	1991	0.20
GDP + AIS ('90)	51.35	15.65	125	22,600	2009	41.56	1990	0.195
GDP + AIS ('95)	53.61	15.95	164	24,800	1996	55.74	1995	0.26
GDP + GCEP (Set IV)* + AIS ('90)	52.91	17.96	109	22,100	2009	38.82	1988	0.20
GDP + GCEP (Set IV)* + AIS ('95)	53.97	17.55	132	22,900	2009	48.28	1993	0.20
350-GW(e) Demand								
GDP + GCEP (Set III) + GC (Set III)	75.31	24.42	199	70,600	2009	77.27	1995	0.315
GDP + GCEP (Set IV) + AGC	70.69	21.49	190	48,700	2009	61.28	1993	0.24
GDP + AIS ('90)	66.27	17.78	162	34,700	2009	45.10	1991	0.21
GDP + AIS ('95)	70.89	19.72	206	53,400	1996	59.70	1995	0.375
GDP + GCEP (Set IV)* + AIS ('90)	67.01	19.78	132	34,000	2009	40.62	1990	0.19
GDP + GECP (Set IV)* + AIS ('95)	69.25	19.93	178	43,300	2009	52.77	1993	0.24

SOURCE: DOE. Uranium Enrichment Strategy Study. p. 69.

Table V-5

SENSITIVITY CASE SUMMARY: LOW SWU DEMAND

	Discounted Total Enterprise Cost ($ × 10^9)	ΔGD only ($ × 10^9)
208 GW(e) in 1993 and Thereafter		
GDP only	51.40	0
GDP + GCEP (Set IV) - 2 Bldgs. only	52.19	+0.8
GDP + GCEP (Set IV) - 2 Bldgs. + AIS ('95)	50.82	-0.6
GDP + GCEP (Set IV) + AIS ('95)	50.44	-1.0
GDP + AIS ('95)	49.12	-2.3

SOURCE: DOE. Uranium Enrichment Strategy Study. p. 71.

enrichment enterprise. This total enterprise cost is relevant because of the possible tradeoff between the amount of uranium and the number of SWUs needed to supply fuel for a nuclear powerplant. For example, if fewer SWUs are produced and sold, more uranium would have to be consumed to fuel the same number of powerplants. 4/

The third column in table V-3 gives the costs incurred in the enrichment process only (without the cost of uranium). The other column headings are self-evident.

350 GWe Demand Base Case

In the 350 GWe case, the GDP capacity is insufficient to satisfy the demand for uranium enrichment, hence some additional capacity is needed. All scenarios in table V-3 with AIS are clearly favored over all scenarios without AIS; hence, in assessing the need for GCEP, it is instructive to compare the projections in the GDP + AIS cases with those of the GDP + GCEP + AIS cases.

According to the UESS projections, if AIS technologies are assumed to first become available in 1995, then the total enterprise cost of producing enriched uranium over the next 30 years is projected to be $1.64 billion less if GCEP is built than if it is not (for the 350 MWe case). In addition, a significant energy savings and lower uranium requirements both also favor the GDP + GCEP + AIS ('95) scenario over GDP + AIS ('95). The uranium requirement is perhaps the most significant factor, because it is questionable that the uranium production projected to be required by 1996 in the GDP + AIS ('95) scenario could be attained. 5/

4/ The tradeoff between SWUs and uranium is explained further in the CRS Report cited in reference 1.

5/ U.S. Department of Energy. Survey of U.S. Uranium Marketing Activity. Washington, July 1980. 21 p. DOE/RA/0053.

If AIS technology is assumed to be available in 1990, then the UESS projects that the total cost will be $0.74 billion greater if GCEP is built than if it is not. However, completion of GCEP still results in a projected energy savings of 30 GW-years compared to the no-GCEP case. Thus, if AIS could be assured by 1990, the UESS projections (for the 350 MWe demand case) indicate that the decision to build GCEP would be a choice between a cost saving and an energy savings. However, work on a pilot AIS plant is not scheduled to begin until FY83 and design of a demonstration facility is not scheduled until 1986. Hence, it is unlikely that a full scale AIS plant could be in operation as early as 1990.

Considering the uncertainties in development of AIS technologies, and since proceeding with GCEP is clearly favored if AIS technology is not available until 1995 and may be favored even if AIS technology is available as early as 1990 (if the projected energy savings is valued over the projected cost savings) the UESS projections support a decision to build GCEP if 350 GWe of nuclear capacity is to be supplied in the year 2000.

250 GWe Demand Base Case

In the 250 GWe case, the existing GDP capacity could conceivably satisfy the entire demand to the year 2000. However, the demand would be very close to the maximum capacity of the diffusion plants. Hence, some extra enrichment capacity would most likely be needed. Since the UESS determined that under any reasonable economic assumptions costs could be lowered by replacing GDP with AIS capacity when it is available, it is again most instructive to compare the GDP + GCEP + AIS scenarios with GDP + AIS scenarios.

In the 250 GWe demand case, with AIS becoming available in 1995, the UESS projects that the total enrichment enterprise cost would be $0.36 billion less

without GCEP than with it (i.e., less in the GDP + AIS ('95) case than in the GDP + GCEP + AIS ('95) case). However, as in the 350 GWe case, there is still a large (32 GW-year) projected energy savings if GCEP is built. It is debatable whether the cost savings or the energy savings would be preferred.

The total Government costs are lower in the GDP + AIS ('95) case than in the scenario with GCEP, but since these costs are recovered, the relatively small difference may not be sufficient to reject building GCEP. The Government costs are lower largely because fewer SWUs are produced without GCEP. The production of fewer SWUs in the no-GCEP scenario leads to a higher projected price per SWU than in the scenario with GCEP. However, again the difference is relatively small and does not present a clear basis for decision regarding building GCEP.

Hence, under the assumption that AIS technology will be introduced in 1995, it appears that the projections of the UESS do not present a clear choice regarding building GCEP in the case of 250 GWe demand.

If AIS technology can be introduced by 1990, the UESS projections for the 250 GWe demand case become somewhat more favorable to the no-GCEP scenario than if AIS technology is not introduced until 1995. The projected cost savings of the GDP + AIS ('90) scenario compared to the GDP + GCEP + AIS ('90) scenario is increased to $1.56 billion, and the projected energy savings in building GCEP is reduced to 16 GW-years. However, it is still not clear whether the cost savings or the energy savings would be preferred.

Hence, it appears that the UESS projections do not provide a clear choice with respect to building GCEP in the 250 GWe demand case regardless of the assumptions made about the availability of AIS technology.

208 GWe Demand Sensitivity Case

For the 208 GWe demand sensitivity case the UESS examines a different set of enrichment supply scenarios than in the base case. In this case it

is possible to satisfy the full demand with only the gaseous diffusion plants.

According to the UESS, at this demand level the GDP-only scenario has a total cost of $0.79 billion less than a scenario that uses GDP plus the first two buildings (of a currently planned total of eight) of GCEP. Since there is little difference between the projected energy use of these two scenarios, the projections favor not building GCEP at this demand level. However, the GDP plus eight-building GCEP scenario is not examined. Since the first two buildings of GCEP would cost 60 percent as much as the eight-building project 6/, projections based on the full eight buildings might show GCEP in a more favorable light. In addition, the scenarios that include AIS are all favored over these two scenarios. Hence, once again to examine the need for GCEP it is useful to compare the GDP + AIS scenario with GDP + GCEP + AIS scenario.

At this demand level, only projections with AIS introduced in 1995 are presented. The GDP + AIS ('95) scenario has a projected cost $1.32 billion dollars lower than the GDP + GCEP +AIS ('95) scenario. However, once again the scenario with GCEP has a projected energy savings relative to the no-GCEP scenario. In this case the energy savings is about 25 to 30 GW-years. 7/ Hence, once again at this demand level, according to the UESS projections, the decision whether to build GCEP involves an equivocal tradeoff between a cost savings and an energy saving.

Replacing Existing Diffusion Plants with Centrifuge Plants

In addition to the projections discussed above, the UESS used another approach to project the cost of SWUs produced by gaseous diffusion and by gas centrifuge

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6/ DOE. Uranium Enrichment Strategy Study. p. 64

7/ Ibid. figure A-28.

techniques to 2010. These projections are based on projections of the capital and operating costs (including power costs) of gaseous diffusion and centrifuge enrichment. They are independent of the demand for enrichment, the price of uranium and other factors that entered in the projections disussed above.

A key factor in these cost projections is the price of electric power, because the diffusion plants require large amounts of power. The study presents projections corresponding to four different assumptions regarding the escalation of electric power costs. Power costs were assumed to escalate at a rate between 1.5 percent and 5 percent faster than the general rate of inflation. These are all lower than the rate experienced in the past decade. However, current projections by DOE and others are for a rate in the middle of the range used. 8/ Because the diffusion process requires about 20 times as much power than the centrifuge process, faster power escalation rates favor earlier replacement of diffusion plants by centrifuge plants.

According to these projections, replacement of 8.8 million SWUs of gaseous diffusion plant capacity by plants using set IV centrifuges, as soon as possible, could reduce the cost of SWUs for all the power escalation rates considered. The projections also indicate that if only set III centrifuges are available, replacement before 1990 of some gaseous diffusion capacity by centrifuge plants could still reduce the cost of SWUs and, for all but the lowest power escalation rate, replacement of at least 5 million SWUs of GDP capacity by set III centrifuges by 1995 would be justified on the basis of a lower cost per SWU.

On the basis of these results, the UESS concludes: "Thus, even if demand continues to deteriorate such that extra [enrichment] capacity becomes available, it appears highly probable that GCEP can still be used in an economic and effective

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8/ Uranium Enrichment Strategy Study. p. 66.

manner by replacing existing GDP capacity." 9/ However, as the projections discussed earlier show, the scenarios that produce the lowest cost of SWUs do not necessarily lead to the lowest total cost to produce enriched uranium, because in other scenarios larger amounts of uranium feed could be substituted for SWUs and result in lower total costs. Hence, even if completing GCEP would result in a lower cost of SWUs in low demand scenarios, it might not provide the lowest total enterprise cost for producing enriched uranium.

In addition, the calculation regarding replacing diffusion capacity with centrifuge capacity does not consider AIS capacity. As the projections discussed earlier indicate, there may be benefits to adding only AIS capacity compared to scenarios that include GCEP.

Thus, the conclusion that GCEP can be used in an economic and effective manner may not be valid in all possible future situations.

CONCLUSIONS

Analysis of the projections of the Uranium Enrichment Strategy Study shows that the cost and energy savings and other potential benefits of building GCEP vary with the demand for nuclear power, date of availability of AIS production, and the price of electric power. Under some scenarios (high demand and late AIS) early completion of GCEP is clearly favored. However, under others (low demand and early AIS) the benefits of completing GCEP are questionable.

The UESS concludes that DOE should "continue GCEP construction without further delay." The study notes that under conditions of low demand and early AIS availability GCEP would "ensure against uncertain demands and contingencies and thereby provide crucial evidence of U.S. credibility as a reliable supplier of

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9/ Uranium Enrichment Strategy Study. op. cit. p. 93.

enrichment services." It also states that, "even if demand continues to deteriorate such that excess capacity becomes available, GCEP can still be used in an economic and effective manner by replacing existing GDP capacity as rapidly as permitted by the current construction schedule." However, as discussed above, this latter conclusion may not be valid if early introduction of AIS is considered as an alternative to GCEP.

In contrast to the conclusion of the UESS, it might be possible to conclude from the same projections that construction of GCEP is not warrented. Such a conclusion could be justified if it were certain that the demand of enrichment will be low, such as would be the case if a policy to phase out nuclear power by not allowing construction of any new plants were adopted. The low nuclear demand conditions of the UESS may come about by market forces, but that cannot be certain.

In most low demand scenarios of the UESS, if GCEP is built, the projected total enrichment enterprise costs are higher and the projected energy use is lower compared to not building GCEP. If one values the projected cost savings possible by not building GCEP over the projected extra energy that will be needed, then one might favor not building GCEP.

The projected tradeoff between costs and energy use is affected by the date of AIS availability. Better information regarding the date of AIS availability may be known by the end of FY82, when DOE is scheduled to select one of three candidate AIS technologies for further development. It may be possible to delay further construction on GCEP until that information is available. However, it should be emphasized that this may be justified only in conjunction with low nuclear growth projections.

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